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Utilization of *Artocarpus heterophyllus Lam* Seeds for Wet Processing of Textiles – as Sizing Agent on Cottons

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Authors' contributions

This work was carried out in collaboration between both authors. Author PA under AICRP – Home Science, Clothing and Textiles Component have designed the study. Authors PA and KSS have performed the study, statistical analysis and wrote the protocol. Author KSS wrote the first draft of the manuscript and managed the literature searches. Authors PA and KSS managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Artocarpus heterophyllus Lam seeds have potential starch content, which can be used for different end uses. Characterization and application of Jack Fruit Seed Starch (JFSS) as a substitute to commercially available, Arrow root starch (ARS) for sizing of cotton fabrics (Cambric and voile) was carried out in the present study. Starch was extracted from *Artocarpus heterophyllus Lam* through isolation method, which gave very fine texture on par with ARS. Scanning Electron Microscopy (SEM) analysis revealed that, the size of JFS ranges between 5.5 to 9.03 µm. The pasting character of JFSS has shown a viscosity of 489 with a peak time at 8.74 min and maintaining gelatinization temperature at 85°C.
5, 10, 15 & 20 percentage of ARS and JFSS were applied to cotton fabric and were tested for geometrical, mechanical and handle properties. Along with control sample (CS) i.e., untreated sample, JFSS treated samples, when tested against ARS treated samples for different fabric

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properties are found to be on-par with ARS treated samples. Apart from CS and ARS treated samples, JFSS treated samples with 10% followed by15% has shown good tear resistance along with stiff hand. Hence, it can be used as a substitute to commercial starches.

Keywords: Wet processing of textiles; cotton fabric; jack fruit seed starch; sizing agent; fabric properties.

1. INTRODCUTION

Starch is a white, tasteless carbohydrate stored in plants is being accumulated in granules (amyloplasts) of roots, corms, tubers, stems, seeds, cotyledons, pericarps and fruits in different amounts in various plant species and varieties. It is low cost, renewable and biodegradable [1]; and does not dissolve in cold water. At higher temperatures with excess water and pressure, granules of the starch collapses and an opalescent colloid solution is resulted know as gelatinization. Gelatinization temperature of the starch is influenced by plant genetic and environmental factors [2].

As sizing agent starch can improve the texture, fineness and drape of the treated fabrics. Sizing helps in improving the efficiency of weaving process, as well provide advantages for subsequent pre-treatments, dyeing and printing stages. Starches are sizing agents that help to keep fabrics clean, as dirt tends to slide off from the smooth finish produces by starching. The commonly used vegetable starches for fabric sizing are sago, wheat flour, maize flour, arrow root, rice starch and tapioca etc., has good demand as a major food sources. Now everyone is focusing on reviewing natural sources for commercial applicability. For instance, Nawab et al. [3] have developed composite films using Mango kernel starch and was evaluated against commercially available Guar gum starch for mechanical, air and water permeability, water solubility and color change properties. Kale et al. [4] have explored the same source to apply on cotton fabric as sizing agent. According to authors, with an increase in starch concentration, an increase in thickness, weight, bending length and flexural rigidity was observed along with decrease in air permeability of fabric. So, in the present study Jack fruit seed starch was explored as agro waste and can be used as a sizing agent.

Jackfruit (*Artocarpus heterophyllus Lam.*) is one the most significant evergreen trees in tropical areas and widely grown in Asia including India, which has a multiple fruit consists of large bulbs along with whitish yellow aril. Each bulb encloses a smooth, oval shaped, brown spermoderm covered by a thin white cotyledon. A single seed is enclosed in white aril encircling a thin brown spermoderm, which covers fleshy white cotyledon. Jackfruit cotyledons are good source of starch (22%) [5] and it increases with seed maturity [6]. The seed is 2-3 cm in long and 1-2 cm in diameter. Up to 500 seeds can be found in a single fruit, which make-up around 8-15% of total fruit weight. Theivasanthi and Alagar [7], investigated JFSS has efficacy against antibacterial (against *E.Coli and B.Megaterium*) property. The objective of this study was to compare JFSS treated samples with commercially available, ARS treated samples. Morphological analysis, viscosity and subjective analysis of the explored starch were analyzed and its fabric parameters *viz*., fabric count, weight, thickness, tear strength, bending length, crease recovery and drape were assessed against arrowroot along with CS.

2. MATERIALS AND METHODS

For sizing/starching fabric, jack fruit seed starch was selected to evaluate against commercially available arrow root starch. JFS were selected from the local market of Hyderabad, Telangana, India. Cambric and Voile fabrics were selected from local market of Hyderabad to treat with selected starches.

2.1 Extraction Method

White aril (seed coats) was peeled off from the cleaned seed and treated with 5% NaOH for 2 min. Brown spermoderm cover can be removed to get fleshy white cotyledons. Seeds sliced into thin chips were subjected to tray dry at 50° - 60°C until reached less than 13 per cent of the moisture content, which were ground with FFC-23 and sieved with 70 mesh flour and refrigerated to < 4^0C after packing. From the grounded flour, starch was extracted through Isolation method.

All India Coordinated Research Project Home Science (AICRP-H.Sc.) has formulated the starch extraction through Isolation method, as a part of project was followed below:

JFS flour was steeped in water for 24hrs (Supernatent was discarded)
↓
Ground the steeped material with 1 % Potassium Meta-bisulphate
↓
Add water making MLR of 1:20
↓
Pass through double fold muslin cloth
↓
Ground the obtained residue and repeat the process until no starch passes
↓
Milky suspension was allowed to settle and supernatant was siphoned off
↓
Treat crude starch with 0.1 N Sodium Hydroxide solutions (stir time to time)
↓
Resultant starch was treated with 0.1 N HCl to get white starch
↓
To make moisture free treat with Acetone
↓
Shade dry and store the starch in air tight container

2.2 Starch Preparation/Gelatinization

Gelatinization/pasting is transformations of starch granules to swollen condition in aqueous solution by gradual increase due to heat. Granules can absorb as much as 30% of moisture of their dry mass and this process is irreversible. As soon as, heat energy is sufficiently high, it dissociates week hydrogen bonds in the granules, thus, increasing its viscosity. Complete solubilization occurs only at high temperatures e.g. 120°C [2].

Typically, starch was gelatinized in water (5% w/v) maintaining 75-80°C of temperature. The gelatinized starch was then cooled down to 60°C. [1]. Selected fabrics were treated with 5, 10, 15 & 20 percentages of AR and JFS starches.

2.3 Subjective Analysis

The subjective analysis was determined by visual analysis for the prepared JFS flour and starch and finished samples. It was assessed by panel of 10 members from the textile background. A schedule was developed on color, texture and appearance and evaluated for the weighted (WMS) mean score on 5 point scale [5-Highly, 4-Moderate, 3-Fair, 2-Poor and 1-Very poor].

WMS = (Sum up all the figures after multiplying frequency with respective weightage / Total size of the sample)

2.4 Compositional Analysis

Compositional analysis was tested at Quality Control Lab, PJTSAU, R'nagar, Hyderabad, Telangana.

2.5 SEM Analysis

AR starch, JFS flour and JFS starch were analyzed through SEM at Ruska lab, Hyderabad. Test samples were suspended in ethanol to obtain a 1% suspension. One drop of the starch-ethanol solution was applied to an aluminum stub using double-sided adhesive tape and the starch was coated with gold–palladium (60:40). An accelerating potential of 9 and 10kV was used during micrograph.

2.6 Viscosity

Pasting characteristics was tested at Quality Control lab, ANGRAU, Hyderabad.

2.7 Objective Analysis

For objective analysis, following geometrical, mechanical and handle properties were analyzed. All the tests were conducted at Apparel & Textiles lab, College of Home Science, PJTSAU, Hyderabad.

2.8 Geometrical Properties

Fabric count: the number of threads per unit measurement was determined for warp and weft ways using IS 1963 – 1969 test method with pick glass. **GSM:** IS No. 1964 – 1970 was used to measure the weight of the fabric.

2.9 Mechanical Properties

Tear strength: the test was conducted on Elmendorf tester using IS 6489-1971method. The obtained reading was calculated in grams using the formula [8] for warp and weft ways:

Tear strength = capacity of the instrument × pointer reading/100

The average tear strength in grams force (gf) was converted into Newton

2.10 Handle Properties

Fabric thickness: Fabric thickness is determined by Heal's thickness gauge and is useful indicators of any change or variation in the fabric handle and appearance [8]. Stiffness: Fabric stiffness is the key factor in the study of handle and drape [8]. Bending length was determined by Shirley fabric stiffness tester and flexural rigidity was calculated from the bending length values. Test method, IS 6490-1971 was employed. Crease recovery: As per IS NO: 4681-1968 test method, SASMIRA crease recovery tester was used to determine the crease recovery angle of the test sample. Drape Coefficient: This was determined as per ISI 8357-1957 using BTRA drape meter.

3. RESULTS AND DISCUSSION

3.1 Raw Material to Yield Ratio of Sources

There was approximately 22% and 40% wastage noticed for JFS flour and starch respectively, as shown in Table 1. As, residue was removed, it resulted in reduced amount of starch, but obtained result is clear, white, free flow starch.

Table 1. Yield ratio of extracted sources

JFS starch at different stages	Weight in gms	
	Flour	Starch
Whole Seeds	1000	1000
Seeds after removal of arils	980	980
After removal of spermoderm	900	900
Milled powder	780	780
Flour / Starch Yield	680	475
Residue	-	125
Total wastage	220	400

3.2 Compositional Analysis

Among all, ARS have more moisture content, which may further degrade quickly compared to JFSS. Bobbio *et al.* [9], have found CHO content of JFSS as 66.2% and Meethal *et al.* [10] has found 68.40% CHO content, which are near to the obtained results. Low protein and ash content reflects good gelatinization, which was present in higher amounts in Jack fruit seed flour than its starch. JFSS have 52.5 per cent of Amylose, where its flour and ARS has 36.7 and 41 per cent resepectively. pH levels of all sources are almost between 6.5 – 6.8, as shown in Table-2.

3.3 Subjective Evaluation - Visual Evaluation

JFSS has milky white color and the color of JFS flour is having tint of light yellow, as shown in Fig. 1. The color of flour may be influence by contenting of various compounds in the raw material. These compounds also influence for the rough texture in the flour, where JFS starch have very fine and soft texture. JFS starch and JFS flour were odorless with mucilaginous texture. When subjected to visual analysis JFS starch have scored highest points than JFS flour, which is less than 50 Percent of JFS starch. See Table 3.

Table 2. Compositional analysis

Composition (100g)	AR starch (%)	JFS flour (%)	JFS starch (%)
Moisture %	15.62	6.34	9.94
CHO	88.28	73.38	88
Protein (g)	0.2	11.83	0.81
Fat (g)	0.56	2.19	0.9
Amylose (g)	41	36.7	52.5
Ash %	0.05	3.74	0.17
pH	6.7	6.8	6.51

Table 3. Visual evaluation of the sources

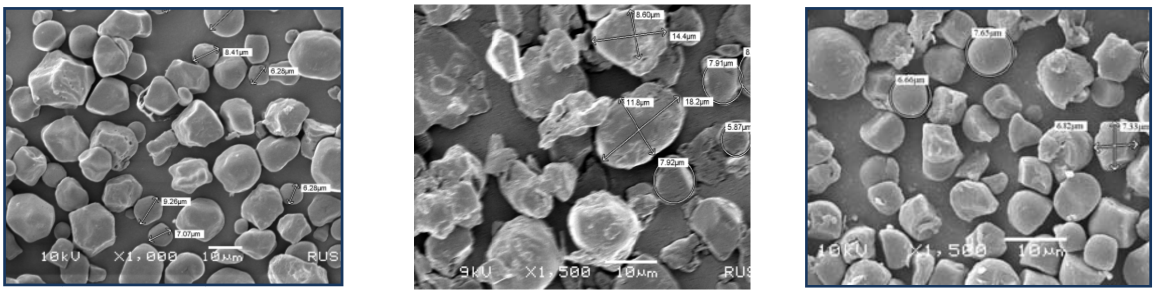
Parameters	Color	Texture	Appearance
JFS Flour	2.3	1.8	2.2
JFS Starch	5	5	5

3.4 SEM Results

The shape and size of starch granules generally vary with plant species and maturity [11]. The starch granules are well dispersed in the sources. The results showed that JFS flour has larger size molecules with 5.87-18 μm, where JFS starch ranges between 5.5-9.03μm under 1500 magnificence. When compared against ARS showed 6.28 - 12.2 μm size granules for 1000X, JFSS resulted to have smaller size molecules, as depicted in Table 4 and Fig. 1. JFSS granules are small and crystal clear which may be due to use of isolation method during extraction process and hence can get good gelatinization. Like ARS, JFSS also possess varying shapes, where as JFS flour granules have shown collapsed oval, round, elliptical and hexagonal shapes [12], where JFS powder granules also possess hexagonal shapes.

3.5 Viscosity

Pasting characteristics of the selected sources were evaluated at Quality Control lab. Pasting temperature of JFS flour (93.25°C) and starch (85.83°C) was in accordance with the 81^{0}C, results obtained by Tulyathan, *et.al.* [13]. However, viscosity of JFS flour and starch was less than AR starch, but JFS starch is more gelatin than JFS flour, as depicted in Table 5.



A. B. C.

Fig. 1. SEM analysis of A. AR starch; B. JFS powder and C. JFS starch

Table. 4 SEM analysis

Parameters	Arrowroot starch	JFS powder	JFS starch
Shape	All shapes mostly Round and dome shape	Elliptical and round	All shapes
Size	6.28-12 μm	5.87-18μm	5.5 to 9.03μm
Magnificence	1000X	1000X	1500X
Dispersion	have good dispersion	have moderate dispersion	have even dispersion

Note: JFS powder source from [12].

Table 5. Pasting characteristics of selected sources

Parameter	Viscosity in centipoise		
	AR Starch	JFS Flour	JFS Starch
Peak time (min)	5.23	8.65	8.74
Gelatinization temperature (^{0}C)	62.45	93.25	85.83
Peak viscosity(RVU)	905	350	432
Viscosity (RVU)	1119	228	489
Set back (RVU)	486	105	214

Considering SEM, viscosity and subjective analysis results of JFS flour and starch, JFS starch was selected for further study to compare against AR starch for objective analysis.

3.6 Objective Analysis

3.6.1 Geometrical properties

3.6.1.1 Fabric count

An increase in number of warp and weft yarns for both type of fabrics were observed for JFSS and ARS treated samples compared to Untreated sample (CS). JFSS and ARS are on par with each other, whereas on warp ways for voile, JFSS has shown increased fabric count than ARS.

3.6.1.2 GSM

Not much difference was observed for 5% starch treatment with both sources for both fabrics, but as the percentage increased, there was increase in fabric weight. Compared to ARS, JFSS has gained more weight. Loose woven structure of the voile material has absorbed more starch, due to which sample increased its weight.

3.6.2 Mechanical properties

3.6.2.1Tear strength

From Table 6, compared to CS, a decrease in strength for cambric and voile fabrics for warp and weft yarns was observed, as the percentage of the starch treatment increased in both the types of starches. Poor strength was observed for 20% ARS treated samples. From 5 to 20 per cent starch application 21.35% to 34.8% and 14.6% to 28.1% reduction in strength was observed for ARS and JFSS samples respectively. Compared to ARS, JFSS holds good strength in all type of tested concentrations (5%, 10%, 15% & 20%). With 20% treatment samples became as stiff as paper, so little slit can tear the fabric completely.

3.6.3 Handle properties

3.6.3.1 Fabric thickness

Increased weight of the cambric fabric resulted increased thickness, due to the starch content present in spaces between the fabric structures. Contrary to cambric, ARS treated voile fabric has shown decrease in the fabric thickness compared to CS, this may be due to the protruding fibers present in CS.

3.6.3.2 Stiffness

Bending length determines the stiffness of the fabric. The bending length values of JFSS and ARS in each concentration level were on-par with each other, but are greater than the control fabric. When, compared to CS all the treated samples have greater bending length, among which ARS treated samples have more stiffness than JFSS samples. Even though the samples treated ARS were having more stiffness, the JFSS treated samples possessed good tear strength property along with the good stiffeness property than AR treated samples followed by control samples.

Vast difference of bending length was noticed towards warp ways of voile fabrics for JFSS and ARS samples. 15% ARS treated samples was almost the double the bending length of CS, which will result in low crease recovery angle. Unlike warp, weft ways of starch treated voile samples with both types of starches have shown almost similar results.

3.6.3.3 Crease recovery

With an increased starch concentration, there was a decrease in the crease recovery angle was observed for both fabrics treated with both starches. Whereas the samples treated with JFSS are having comparatively greater crease recovery angle towards warp and weft ways than ARS treated samples, which indicates that the samples treated with ARS treated samples are stiffer than JFSS; this in turn reduces the tear strength of the fabric. Among all the cambric weft ways with 20% starch showed 50% and 40.33% reduction in the crease recovery angle for ARS and 20% JFSS treated samples respectively.

3.6.3.4 Drape co-efficient

With an increase in the percentage of the starch application, an increase in drape co-efficient was observed for both types of starch treatments. ARS have less drape ability than JFSS in all the concentrations. 20% JFSS for cambric fabric has show approximately 47.5% increase in the drape, where as 20% ARS treated samples have shown 33.3% increase. Like cambric, voile also has minimal drape ability with an increase in the concentration of starch solution. In comparison to CS, not much difference was noticed for 5% ARS treated sample.

Table 6. Objective analysis of tested samples

Parameters		Effect on Cambric fabric properties for JFS starch treated samples against AR starch and control								
		Control	AR starch				JFS starch			
	Starch %	-	5	10	15	20	5	10	15	20
Fabric count	Warp	86.6	86.8	87.6	88.2	89.8	88.8	89.6	90.6	91.4
	Weft	62.6	62.8	65.2	65.8	68.8	64.4	64.8	65.6	67.4
Weight (GSM)	-	79.4	79.88	80.7	81.6	82.38	80.2	81.72	82.12	84.4
Thickness (mm)	-	0.268	0.247	0.252	0.259	0.262	0.272	0.284	0.29	0.306
Tear strength (g.f)	Warp	1305.6	1024	985.6	819.2	729.6	1190.4	998.4	883.4	793.6
	Weft	640	435	460.8	358.4	345.6	576	499.2	409.6	358.4
Bending length (cm)	Warp	1.87	2.34	2.73	2.93	3.03	2.27	2.5	2.64	2.83
	Weft	1.15	1.41	1.65	1.73	1.89	1.49	1.57	1.51	1.73
Crease recovery (angle)	Warp	69	51.2	46	41.8	37.2	61.6	55.8	48	44.8
	Weft	84.8	61.6	53.8	49.2	42.4	69.2	60.6	54.8	50.6
Drape co-efficient	-	40.22	42.12	48.58	50.47	53.62	51.26	55.52	58.67	59.3
Effect on Voile fabric properties for JFS starch treated samples against AR starch and control										
Fabric count	Warp	66.2	64.6	64.2	64.6	65.4	63.6	65.2	67.2	66.2
	Weft	52.6	52.8	53	53.2	55.8	53	53.4	54	55.6
Weight (GSM)	-	64	64.3	64.58	65.34	67.7	64.72	66.5	67.54	69.32
Thickness (mm)	-	0.248	0.25	0.259	0.27	0.278	0.256	0.268	0.28	0.29
Tear strength	Warp	1139.2	896	844.8	780.8	742.4	972.8	908.8	844.8	819.2
	Weft	614.4	486.4	384	332.8	323.17	563.2	486.4	435.2	422.4
Bending length (cm)	Warp	1.15	1.8	2.06	2.26	2.51	1.49	1.6	1.53	1.75
	Weft	1.11	1.28	1.52	1.64	1.74	1.39	1.53	1.7	1.85
Crease recovery (angle)	Warp	72.2	58.6	50.6	46.2	41	61	53.4	47	43
	Weft	79.8	61	53.4	51.6	44	65.8	57.4	50	45.8
Drape co-efficient	-	41.79	45.74	50.78	52.99	57.41	52.05	53.78	56.78	58.51

4. CONCLUSION

From the present study, a unique natural source, Jack fruit seeds were identified as a good source of starch to treat on cotton fabrics for stiffness.

With an increase in the starch percent, there was a decrease in the tear strength was observed. When compared to AR starch, JFSS treated samples possess good tensile strength and also have greater crease recovery angle in warp ways, which indicated that the samples treated with ARS have become stiffer than JFSS treated samples. Even ARS treated sample were having more stiffness, the JFSS treated sample possessed good tear strength property along with the stiff hand followed by ARS treated samples and control samples. From the obtained objective analysis it can be summarized that jack fruit seed starch can be used as a substitute for starching of cottons. To recapitulate, 10 per cent JFSS stiffness is having good tear strength. Hence, it can be employed to stiffen the fabrics.

Observation: While applying JFS starch, the feel of gelatin content was much lower than AR starch. But, an immense difference in its stiffness was noticed after sample was dried i.e., compared to AR starch treated samples, JFS starch treated samples have shown very good stiffness after drying.

5. IMPLICATIONS OF THE STUDY

Scientists and researcher scholars can explore and identify other agro waste sources; can compare, identified sources with commonly available sources; further study can be carried out on application as stiffening/thickening agents on other type of fabric; and can be explored its usage in other textile applications.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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